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Development of TIG Welding System for a Nuclear Fuel Test Rig

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1. Introduction

The rod inner pressure, centerline temperature, coolant temperature, and neutron flux resulting from the irradiation properties of nuclear fuels are important factors for evaluating nuclear fuel properties in pile. To measure this various irradiation characteristics of the nuclear fuel, most of the special sensors such as a TC (thermocouple), LVDT (linear variable differential transformer), and SPND (self-powered neutron detector) mounted in and out of nuclear fuel test rig and rods are attached by a welding process [1-2]. The welding process is one of the most important among the instrumentation processes of the nuclear fuel test rig and rods. To manufacture the nuclear fuel test rig, a precision welding system needs to be fabricated to develop various welding technologies of the fuel test rig and rods jointing the various sensors and end caps on a fuel cladding tube, which is charged with fuel pellets and component parts. Thus, we designed and fabricated the precision welding system consisting of an orbital TIG welder, a low-pressure chamber, and a high-pressure chamber. Using this system, the performance tests were performed with the round and seal spot welds for each welding condition.

This paper describes not only the contents for the fabrication of precision TIG welding system but also some results from weld tests using the low-pressure and high-pressure chambers to verify the performance of this system.

2. TIG welding system

A TIG welding system has been configured to be able to weld the nuclear fuel test rig and rods by applying the TIG welder using the low-pressure chamber and high-pressure chambers. As shown in Fig. 1, the TIG welding system consists of mainly three parts, an orbital TIG welder, a low-pressure chamber and a high-pressure chamber. The orbital TIG welder acts as a power source for each weld processes preformed in the low-pressure and high-pressure chambers. The low-pressure and high-pressure chambers are installed with a vacuum pump and a gas supply system to keep an inert gas atmosphere for the weld processes. The low-pressure chamber is used to get the welded surface of the nuclear fuel test rig and rods clean with the inert gas filled inside the chamber. Also, the high-pressure chamber is used to weld a pin-hole of a nuclear fuel test rod filled with helium gas, and the nuclear fuel test rod sealed with this spot welding process should not leak helium.

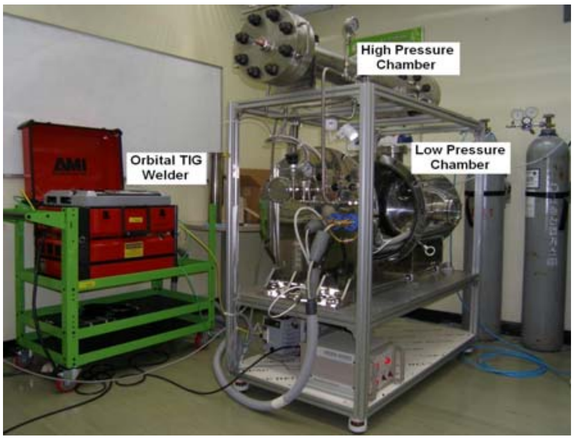

Fig. 1 TIG welding system for the manufacture of the nuclear fuel test rig and rod

2.1 Orbital TIG Welder

The orbital TIG welder (AMI, M-207A) is a complete welding system intended for fusion welding of metal tubes, pipes, and fittings. It consists of a power supply, a water cooling unit, gas lines, and a tube welding head (Model No. 9-1500). The power supply controlled by a microprocessor provides GTAW current with pulsation controls, high frequency arc starting, purge gas controls, weld head arc rotation, and automatic timing functions. The microprocessor can store up to 100 different welding schedules in its memory for rapid access. The water cooling unit is used to cool a welding head. It cannot be operated without coolant in the tank or without a water flow path (circulation through a weld head). The gas lines are Teflon tubes to supply inert gas in a welding head. The orbital TIG welder is equipped with a motor servo controller in an orbital weld head that provides the power and regulation for rotating the arc around the weld seam of a specimen. It can also be used as a manual welding power source using an optional manual torch [3].

2.2 Low-Pressure Chamber

A low-pressure chamber has the design specifications of a 500mm diameter and 600mm length and is made of AISI 304 stainless steel. It is able to mount 2 pipes of a 50.8mm diameter and 600mm length on its front and rear and remove those.

Thus, it is possible to weld a long tube. This chamber is used to weld the joint surface between a cladding tube and an end cap of the nuclear fuel test rod. It can also be used to weld assembly parts of the nuclear fuel test rig. Its inside was installed with sample holders and a weld head as shown in Fig 2. All the orbital welding process in the low-pressure chamber is automatically implemented with the weld head supplied with programmed weld parameters.

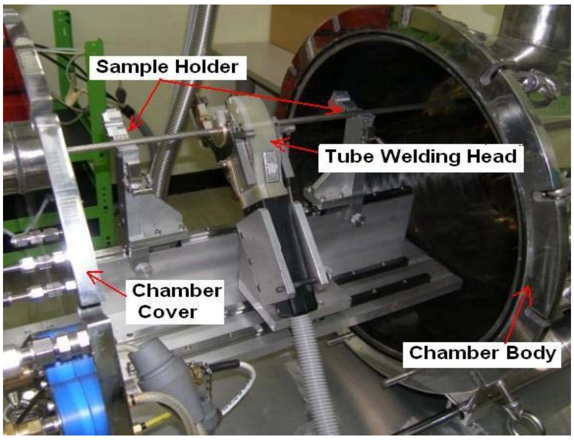

Fig. 2 Photograph of the low pressure chamber installed with sample holders and an orbital weld head

In performance tests, a base material of the fuel test rods is Zr-4. The size of cladding tubes is O.D: 9.0 mm, I.D: 8.4mm. The soundness of the welded specimen has been confirmed through visual inspection and microstructure analyses.

2.3 High-Pressure Chamber

A high-pressure chamber has the design specifications of a 150mm diameter and 1200mm length. Its material is AISI 304 stainless steel. It is comprised of a chamber part and a spot weld tool, which needs to set the position of a specimen. The spot weld performed in the high-pressure chamber is to seal a pin-hole of the fuel test rod which is filled with helium gas. The fuel test rod welded with this process should not leak helium gas out of its outside, when it is taken out of the high-pressure chamber. In this process, filling up helium gas inside the nuclear fuel test rod is to prevent the depression of the cladding tube during the combustion goal of the test fuels and to improve the heat transfer coefficient of a gap between pellets and cladding [4]. To weld a pin-hole, the view of the high-pressure chamber putting a spot weld tool is shown in Fig. 3. The seal spot weld process was as follows: First, a nuclear fuel test rod is fixed in the spot weld tool according to a pin-hole and an electrode (-), and then put it into the high-pressure chamber. Second, after vacuuming the chamber, a nuclear fuel test rod is filled with helium gas according to the pressure conditions. Finally, turn on the TIG welder presented for the weld conditions.

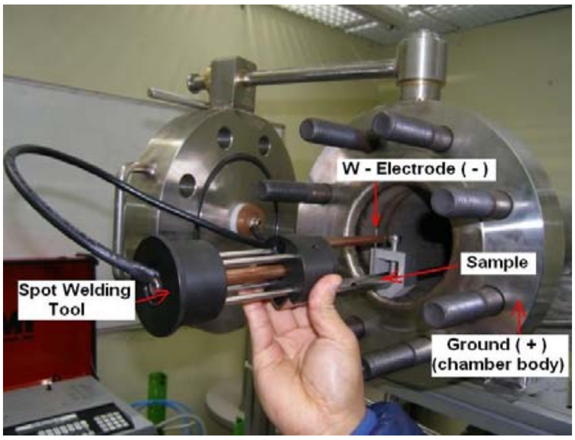

Fig. 3 View of the high-pressure chamber mounting a spot weld tool

In performance tests, the base material of a fuel test rod is Zr-4, and a pin-hole size of the specimens is 0.9mm in diameter. The results have shown a good weld-ability at welding current of a 30A and welding time of 0.4sec in helium gas atmosphere (5bar).

3. Conclusions

The TIG welding system was developed to manufacture the nuclear fuel test rig and rods. It has been configured to be able to weld the nuclear fuel test rigs and rods by applying the TIG welder using a low-pressure chamber and a high-pressure chamber. The performance tests using this system were performed with the round and seal spot welds for the welding conditions. The soundness of the orbital TIG welding system was confirmed through performance tests in the low-pressure and high-pressure chambers.

REFERENCES

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